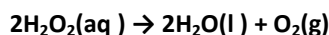


## T06D08 – Elephants Toothpaste (Happy St. Patty's Day)

Hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) is a liquid at STP which does not have enough energy to overcome the  $E_a$  in order to decompose. Small changes in the  $E_a$  can be made by the addition of a catalyst such as UV radiation – which is why it's generally stored in a dark place or in a bottle with minimal transmittance of light. Other catalysts can be used to lower the  $E_a$  such as  $\text{MnO}_2$  (manganese dioxide), potassium iodide (KI) and many transition metals. For this experiment I recommend the use of potassium iodide.

The overall reaction of the decomposition of hydrogen peroxide is as follows:



As has been discussed in HL material, the addition of a catalyst lowers the  $E_a$  by providing an alternative mechanism to the reaction. The elementary steps for the reaction are theoretical and the intermediates (unless rate determining) do not appear in the overall rate law of the equation.

For  $\text{H}_2\text{O}_2$  the mechanism of catalysis using potassium iodide, KI, involves only the  $\text{I}^-$  ion meaning that an aqueous solution of KI will allow for a better reaction. The mechanism involves two steps as follows:



Second step regenerates the  $\text{I}^-$  ion (confirming that it acts as a catalyst since it returns to its original state). Since the first step is the slow step, it's also then the rate-determining step, and alone will make up the rate law.

Using the discussion from last class (IB 16.2), the coefficients of the elementary step can be used to determine the rate law:

$$\text{Rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$$

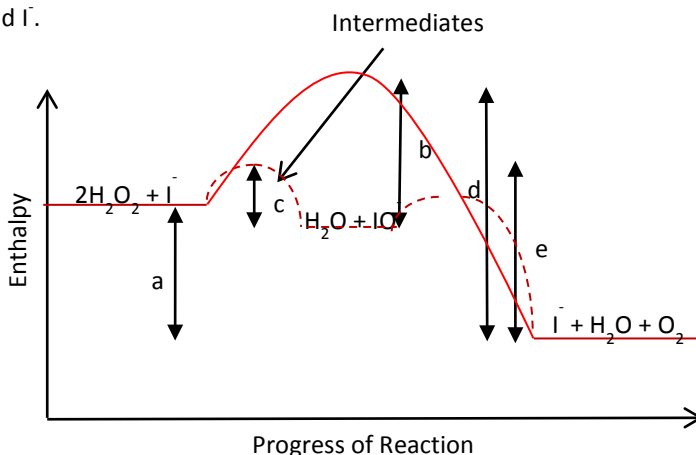
Thus, this reaction is first order with respect to both  $\text{H}_2\text{O}_2$  and  $\text{I}^-$ .

The reaction is also notably exothermic.

Uncatalyzed Reaction ———

KI Catalyzed Reaction - - - - -

- a) Enthalpy ( $\Delta H_{\text{rxn}}$ ) stays the same
- b) Forward energy barrier ( $E_a$ ) of un-catalyzed
- c) Forward energy barrier ( $E_a$ ) of KI catalyzed
- d) Reverse energy barrier ( $E_a$ ) of un-catalyzed
- e) Reverse energy barrier ( $E_a$ ) of KI catalyzed



Have the students walk you through how you can confirm this rate law, but lead them to a set-up similar to the one below. If you complete each trial at the same time in several different 500mL or 1L grad cylinders, you can really see the relative rates of reaction. Have them put them in order of their predicted reaction rates so it's easy to visually see the reaction rates.

Be sure to cover the desk with large plastic bags. Fill each graduated cylinder with the  $\text{H}_2\text{O}_2$  solution, about 5mL of liquid soap, and food coloring if desired. The last step will be to have 6 student volunteers pour KI(aq) into respective GC's and enjoy!

Volume of $\text{H}_2\text{O}_2$ (mL)	$[\text{H}_2\text{O}_2]$ (%)	Volume of $\text{I}^-$	$[\text{I}^-]$ (mol dm <sup>-3</sup> )	Predicted Relative Rate
50.00	30.0	25.00	3.0	X24
50.00	15.0	25.00	3.0	X12
50.00	15.0	25.00	1.5	X6
50.00	15.0	25.00	1.0	X4
50.00	15.0	25.00	0.5	X2
50.00	7.5	25.00	0.5	X1

Read more:

[http://wiki.answers.com/Q/Why\\_is\\_KI\\_a\\_catalyst\\_for\\_H2O2\\_decomposition\\_but\\_KBr\\_and\\_KCl\\_aren%27t#ixzz1GrQi9clr](http://wiki.answers.com/Q/Why_is_KI_a_catalyst_for_H2O2_decomposition_but_KBr_and_KCl_aren%27t#ixzz1GrQi9clr)

The following table of results is what we as a class, using very rough quantitative means, were able to determine. All it all the lab was a success in that it accomplished the goal of visually demonstrating the change in reaction rate due to the concentration of both the starting material and a catalyst.

Grad Cyl.	[H <sub>2</sub> O <sub>2</sub> ] (%)	[I <sup>-</sup> ] (mol dm <sup>-3</sup> )	Predicted Rate	Time (s)	Volume (cm <sup>3</sup> )	Rate (cm <sup>3</sup> /s)
1	30.0	3.0	X24	6.25	500	80.0
2	15.0	3.0	X12	17.15	500	29.1
3	15.0	1.5	X6	30.37	500	16.5
4	15.0	1.0	X4	38.28	500	13.1
5	15.0	0.5	X2	115.06	500	4.35
6	7.5	0.5	X1	465.15	500	1.07

It's also a good idea to have students make each of the solutions, from a stock of 30% H<sub>2</sub>O<sub>2</sub>(aq) and KI(s). It gives them practice in stoichiometric calculations, conversions, and dilutions.